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SOME FINDINGS ON THE APPLICATIONS OF ERTS AND SKYLAB IMAGERY FOR METROPOLITAN LAND USE ANALYSIS

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ABSTRACT

Work undertaken on a three-sensor land use data evaluation for a portion of the Phoenix area is reported. Analyses between land use data generated from 1970 high-altitude photography and that detectable from ERTS and Skylab, especially in terms of changes in land use indicate that ERTS and Skylab imagery can be used effectively to detect and identify areas of post-1970 land use change, especially those documenting urban expansion at the rural-urban fringe. Significant preliminary findings on the utility of ERTS and Skylab data for metropolitan land use analysis, substantiated by evaluations with 1970 and 1972 ground control land use data are reported.

1. INTRODUCTION

For several years, the Office of the Chief Geographer of the U.S. Geological Survey has been investigating the use of remote sensors aboard high-altitude aircraft and earth-orbiting satellites for a variety of geographic concerns. Two of the many applications which have been and continue to be of special interest are in the areas of land use and urban analysis. The "Census Cities Project" of the Office of the Chief Geographer was established in 1969 with responsibility for investigating the use of high-altitude aircraft and satellite-borne remote sensors for urban land use inventory and urban land use change detection. In 1970, during the time of the decennial census, and again in 1972, NASA high-flight aerial photography was obtained for a 10 percent rank-size sample of U.S. urbanized areas. Using this photography, maps of land use and land use change were produced for some of these urban areas. These data now serve as a base upon which to evaluate the utility of satellite imagery for urban land use inventory, and especially for change detection to update the existing land use data bases.

With the launching of the ERTS and Skylab satellites, we have entered a new era of unparalleled earth resources observations, inventory, and analysis. Research undertaken to tap the information contained in these satellite images will help to build upon and improve our knowledge of one of the earth's most valuable and critical resources -- land and man's use of the land. To meet this challenge, a study was undertaken on a three-sensor land use data evaluation for a portion of the Phoenix, Arizona area. A 1970 land use data base was generated for the Phoenix urban test site from high-altitude aircraft photography and 1972 changes in land use were documented using ERTS-underflight photography. These data serve as a base upon which to evaluate the ERTS imagery for land use analysis and to conduct a substantive review of the Skylab imagery for this purpose.

This paper documents research in which imagery from the ERTS-1 multispectral scanner overpasses of October 16, 1972 and May 2, 1973 and from Skylab 2 (EREP) taken by the S-190A multispectral camera in June 1973 were analyzed for the Phoenix test site. Analyses between land use data generated from 1970 high-altitude photography and that detectable from ERTS and Skylab were made to determine how effectively ERTS and Skylab imagery can be used to detect and identify areas of post-1970 land use change, especially those occurring at the rural-urban fringe which document some of the processes of urban expansion.

2. DESCRIPTION OF TEST SITE

Selection of the Phoenix area, as opposed to other urban test sites under study, was based on three factors: 1) the completeness of the land use data base for the Phoenix test site, 2) the early availability of ERTS and Skylab imagery, 3) the receipt of good quality satellite images.

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The Phoenix urban area is one of eight cities being analyzed under NASA-funded ERTS and Skylab experiments in urban change detection. For the entire Phoenix test site, which encompasses 11 individual 20 x 20 km sheets (Figure 1), 1970 land use and 1970-1972 changes in land use have been mapped from NASA high-altitude aerial photography at a scale of 1:100,000 and at a minimum parcel size of 4 hectares. Land use was mapped according to the USDI/USGS Level II Land Use Classification System recommended for nationwide application (Figure 2). Area measurements of individual 1970 and 1972 land use polygons have been calculated and reported by census statistical area for the entire Phoenix test site. This comprehensive land use data base and accompanying statistical tabulations will comprise the component pages of a proposed Atlas of Urban and Regional Change, a looseleaf user-oriented product, whose design is part of the experiment.

3. ERTS AND SKYLAB IMAGERY: QUICK-LOOK APPRAISAL

An examination of the ERTS and Skylab imagery of the Phoenix study area reveals that much information can be garnered on land use in and around an urban setting (Figure 3). A quick-look evaluation was made of ERTS color infrared 1:100,000 scale enlargements of the October 1972 and May 1973 scenes, and each of the individual Skylab black-and-white and color bands from the multispectral camera (S-190A). This analysis indicated that certain types of land use data which are vital to urban change detection can be identified.

The color infrared imagery, both from the ERTS and Skylab missions, offers better intra-urban contrast of land use types, especially between residential subdivisions (pink) and commercial/industrial land use (blue) than afforded by either the black-and-white or natural color scenes. Areas under construction show up well by their bright spectral response. Pronounced differences between irrigated cultivated fields and fields lying fallow near the urban edge of the Phoenix area (possibly being held idle or in a less intensive stage of agricultural usage in anticipation of future urban development) can be clearly distinguished. Some areas of urban irrigated open space (golf courses and parks) are readily discernible by their pale pink spectral response in the color infrared scene. These areas can be contrasted with isolated patches of agricultural land within the urban area which exhibit a deep red appearance.

The natural color 70mm transparency taken by the S-190A multispectral camera aboard Skylab 2 in June, 1973 is one of five different film and spectral band combinations received for the Phoenix area, each camera recording the same scene simultaneously and each band offering a unique input into the study of the area. A quick-look appraisal of the color photograph indicates that it is of high quality and the high resolution lends itself well to detailed land use analysis, although the information that can be extracted from the imagery is greatly enhanced when complemented by scenes in the different spectral bands. The color photography from Skylab 2 provides very clear definition of the boundary between urban and built-up land use and adjacent agricultural land. This permits an accurate delimitation of the urban area of Phoenix on the basis of land use.

Residential land use is most readily distinguishable on the color photography, but intra-urban land use distinctions cannot be discerned easily from the color photography alone. Changes that have occurred at the urban-rural boundary since 1970 involving the conversions of non-urban land to urban use, particularly additions of residential land, are visible on the color photography, as are sites presently undergoing land use change.

The black-and-white green band shows less information than either of the color photos, but the main advantage of having black-and-white multispectral coverage in the green, red, and infrared wavelengths is in the variant spectral responses of some features which enable their identification from a comparative spectral analysis. In addition, each of the black-and-white bands can be combined with appropriate filters in the photo lab to produce either a false color infrared scene or enhanced by a variety of other additive color techniques.

The black-and-white photo taken in the red portion of the electromagnetic spectrum shows similarity in land use detail to that displayed in the green band. Most very bright responses displayed by some features on the photo are due to different reflectivity of roof-top materials (most bright spots correspond to commercial/industrial activities) and the higher albedo from bare soil most indicative of cleared fields and land under construction (new cultural features).

At first glance, it appears that the black-and-white near infrared photograph from the S-190A camera holds little information for urban analysis other than clear water body demarcation. A closer inspection, however, reveals that this scene contains much intra-urban land use data. The black-and-white infrared band provides for good delineation of intra- and inter-urban transportation networks. Major streets, railroads, and airfields can be mapped from this Skylab 2 image. Also, areas of commercial development within the urban area can be delineated using the black-and-white IR photography. The commercial ribbon development along Grand Avenue which runs diagonally NW-SE into the center of the city and merges with the intense commercial activity in the Phoenix central business district is clearly visible. In addition, larger regional shopping centers can be mapped from the black-and-white IR image and some commercial development at nodes of intersecting section lines can be seen. Good correlation between the bright spot response of land use types in the red and green bands and the dark response of commercial/industrial development in the infrared scene illustrates, how when used together, one can extract clues as to the identity of certain land use features from each of the multispectral signatures.

Because of the availability of high-altitude photo coverage of the same or near time period, we are offered a unique opportunity to compare what can be mapped from ERTS and Skylab imagery with "ground control" data. Since the nature of land use patterns reflected in and around most urban areas is dynamic, periodic aircraft and satellite imagery can be used to appraise recent and present changes in land use, and the trends which these changes portend.

There are several dynamic areas in the Phoenix test site where rapid conversion of non-urban (mostly agricultural) land use to urban residential suburbs is occurring. One of these locations is Sun City, which lies to the northwest of Phoenix. Changes in this development can be documented from a series of high-altitude photographs of the area beginning in 1969. Figure 4 shows the development as it appeared in 1970 on the high altitude aircraft photography from which the initial land use inventory was made. It also shows the Sun City development in 1973 as it appears in a photo enlargement of the Skylab image. It is possible to map the changes in land use from 1970 to 1972 using the ERTS imagery. Further changes in land use can be seen in the Skylab image. Particularly striking is the clarity in land use detail evidenced in the Skylab image. Several changes can be noted since the time of the high altitude photograph: beginning of a new ring of housing to the north, residential fill-in of the second ring, scraping of agricultural areas to the north and south, and disappearance of a portion of the lake on the right. The ability to extract this kind and level of land use data from the newly-acquired satellite imagery, prompted us to undertake a more detailed analysis of ERTS and Skylab to determine whether or not actual instances of land use change could be documented from the imagery.

4. LAND USE AND CHANGE ANALYSIS

The index in figure 1 shows each of the 20 x 20 Km sheets for which land use has been mapped and 1970-1972 land use changes have been documented. This area covers only a fraction of the entire ERTS and Skylab images of the Phoenix site. Due to time constraints, it was not possible to do a detailed analysis of the entire 4400 sq km Phoenix test site, so a small segment corresponding to one of the eleven 20 x 20 Km sheets for which 1970 land use was mapped was chosen for intensive study (Figure 1). This area lies on the western edge of the Phoenix urban area; part of Sun City appears in the northwest corner of the sheet. This area was selected because it straddles the urban-rural interface and, therefore, the likelihood of encountering land use changes due to conversions of land from rural to urban use would be greater than in either a wholly urban or non-urban sheet.

Once the test area had been determined, appropriate ERTS and Skylab passes were selected. Black-and-white bands 4, 5 and 7 in 70 mm format from the ERTS-1 overpasses of October 1972 (1085-17330) and May 1973 (1283-17334) were combined photographically to make two false color infrared composite cibachrome prints enlarged to a scale of 1:100,000. This is the same scale as the 1970 land use analysis from high-altitude aerial photography. Similarly, portions of Skylab 2 S-190A 70 mm natural color and color infrared images taken by the multispectral camera were enlarged also to a 1:100,000 scale of analysis. Frosted stable-base drafting film overlays were registered to both the October 1972 ERTS and June 1973 Skylab color IR print enlargements. Interpretations were made by un-aided visual inspection. The minimum mapping unit was a land use polygon 2 mm x 2 mm in size. Land use was mapped according to a "modified" version of the Level II classification system. Table 1 shows a systems comparison of the high-altitude photography, ERTS, and Skylab imagery in terms of a number of parameters including types of land use categories mapped from each in the Phoenix study area. While the level of land use detail extracted from the ERTS and Skylab imagery appears nearly identical, it was found easier, and therefore faster, to extract this land use data from the Skylab photography. (It is estimated that the land use analysis from the ERTS image was done in one-half the time as the high-altitude photo interpretation; the Skylab interpretation was slightly less.) Also, there was considerably more confidence in the reliability of boundary and category designations from Skylab than from ERTS. This is due to better resolution of the Skylab 190A system, larger initial scale (which required a smaller photo enlargement factor) and the availability of companion high resolution natural color photography for supplemental reference.

In order to determine the degree to which actual changes in land use, especially those signaling growth at the urban periphery since 1970, have been detected from the satellite imagery, a comparison was made of the land use data generated from each of the three sensor/platform systems. The land use map made from the 1:100,000 photo enlargement of the October 1972 ERTS-1 scene was first compared to the corresponding aerial photo-derived land use interpretation at the same scale (Figures 5 and 6A). It can be seen that there is fairly close correspondence between the land use category designations on both the ERTS and aircraft interpretations. However, boundary delimitation comparability is noticeably poor. This is due to degraded image quality resulting from a combination of low system resolution and photographic enlargement which considerably reduced image definition. In addition, direct comparisons between photo and satellite image land use interpretations are further complicated by differences in the level of land use aggregation and the classification system used. As a result, direct polygon-for-polygon comparisons between ERTS and photo-derived land use data were not practical. This finding is also supported by research conducted elsewhere (Simpson, 1974).

A more realistic appraisal of the ERTS-derived land use data for change detection was through an ERTS-to-ERTS comparison. The October 1972 land use overlay was compared with the land use displayed on a color enlargement of the May 1973 ERTS scene and changes noted. This proved to be a more meaningful technique for evaluating the satellite data. Changes noted in the seven-month interval were analyzed and only seemingly valid changes were coded according to a two-digit "from-to" notation (Figure 6B). Seasonal changes in vegetation growth and cultivation cycle were disregarded. A striking change in land use occurs in the area south of Sun City where previously agricultural land is presently undergoing change, evidenced by construction activity, indicating probable further urban development. This demonstrates a unique aspect of the remote sensor -- through repetitive satellite coverage, changes taking place, i.e., land under construction can be "flagged" as dynamic areas to watch for changes to occur at some future time thus enabling the effective monitoring of the direction and trends of future urban development and growth. The ability to detect these "disturbed" areas from the ERTS image attests to its value as a tool in urban change detection analysis.

The Skylab 190-A land use interpretation exhibits still another level of analysis intermediate between the photo and ERTS data. It contains more detail than that of the ERTS-derived data, therefore it can be useful as a supplemental reference to aid in interpreting the ERTS imagery. There is greater category and boundary comparability between the land use data from Skylab and that mapped from the high-altitude photography (Figure 7). The main disadvantage of the Skylab platform is that it is non-repetitive; most coverage is on a one-time basis. Therefore, it cannot be used to monitor growth and changes within an area over time.

The main thrust of this research was to map land use conditions at the urban edge of the Phoenix study area as indicators of urban area growth. This is of vital concern especially in the rapidly expanding Phoenix urban area where annually large areas of irrigated agricultural land are converted to urban use. The ability to detect and monitor this growth in terms of the kind, magnitude, direction, and trends would prove valuable in assessing conditions of the urban environment. An evaluation of the capability of the Skylab EREP sensors to document the 1973 expansion of the Phoenix urban area was undertaken. Using solely the land use interpretation made from the Skylab S-190A color enlargement, an unbroken continuous line was drawn around the outermost edge of the urban and built-up land use area. This boundary which thus defines the limit of the Phoenix urbanized area for the sample site based on 1973 land use conditions derived from Skylab imagery was then compared with the urban and built-up delimitation for the same area based on 1970 land use as it was mapped from the high-altitude photo interpretation (Figure 8). By superimposing the two urban area delimitations, we can see that, for the most part, there is good correlation between them. But where there are differences between the two boundaries, to what extent do the differences reflect post-1970 changes in land use picked-up from the Skylab interpretation?

As reported previously, 1970-1972 land use changes have been documented from high-altitude photography. Figure 9 shows these change areas superimposed on the 1970 urbanized area boundary which in turn is displayed on an enlargement of the Skylab color image. Only the actual change polygons were mapped and coded according to a two-digit notation identifying both the previous and new use, respectively. All of these changes have been verified in the field. It can be seen that most changes between 1970-1972 involved transition from agriculture (6) to single-family residential land use (4). The second-most prevalent change noted were those areas in a transitional state indicated by an asterisk (*). These are areas under construction whose new use is not yet apparent. The change polygons were then registered to the 1973 urban and built-up land use boundary determined from the Skylab imagery. Figure 10 shows clearly that most of these changes were in fact accurately identified and incorporated into the 1973 urban area. Also, some cases involving land which in 1970 was in a transitional state (*) has since undergone completed change and the new use has been identified. In addition to picking-up post-1970 changes in land use, there are a number of instances where additional built-up land use, not noted in 1972 as being developed, are identified from the Skylab imagery. While these cases have not been documented by field observation, their identity has been inferred through correlation with the signature of similar areas whose use has been determined. This indicates with much certainty that further occurrences of urban land use change beyond 1972 have been mapped from the Skylab EREP imagery. Specifically, we have been able to document a 3 percent increase in residential land use between 1972 and 1973 which demonstrates that the satellite imagery can be used to update portions of the 1972 land use data base.

5. SUMMARY AND CONCLUSIONS

Analysis of ERTS-1 and Skylab 2 EREP imagery alone and in comparison with land use data generated from 1970 and 1972 high-altitude photography indicates that certain categories of intra-urban land use can be identified from the satellite imagery. However, the degree to which these categories of urban land use can be mapped depends greatly on the size of the use polygons and their contrast ratio with the surrounding uses. In general, more intra-urban land use detail could be extracted from the Skylab color infrared scene than from either the ERTS or other Skylab images. Land use category identification from ERTS and Skylab compared favorably with that mapped from the high-altitude photography, whereas, there was less correspondence between boundary delimitations particularly from the ERTS imagery due to degraded resolution as a result of photo enlargement. This clearly indicates a need to reconcile the inverse trade off between scale (level of analysis) and resolution.

Many areas of post-1970 and post-1972 land use changes at the rural-urban fringe and those changes involving large tracts of land in other areas could be easily and accurately identified both on the ERTS and particularly on the Skylab imagery. Small intra-urban land use changes, however, could not be readily discerned. Most of the changes mapped involved conversion of agricultural land to residential use. A 3 percent addition of urban residential land in 1973 (1200 hectares) was documented from the Skylab 2 imagery in the 20X20 km study area. This information proved of value in updating portions of the 1972 land use data base for this area.

Land use interpretations from the ERTS and Skylab imagery were completed in a fraction of the time it required to do the same analysis from the high-flight photography. However, land use detail and accuracy level were not as fine-grained in the satellite compilations. As an effective change detection tool, the ERTS platform is quite viable, having the unparalleled advantage of repetitive coverage. Even with the merit of EREP's superior sensor system, Skylab imagery offers only a one-time land use appraisal; it can perhaps best be considered as 1973 support-underflight data for ERTS.

A number of likely applications and follow-on analyses are suggested by this evaluation of ERTS and Skylab imagery, some of which build upon and update a list of uses which have been identified under other phases of the project. Some of these applications are: 1) estimate water use requirements; 2) define urban expansion; 3) document the pattern of residential development and assess quality of residential environment; 4) project future population densities, and estimate changes in population distribution between censuses; 5) assess environmental impact resulting from gradual as well as catastrophic changes.

REFERENCES

Anderson, James R., E. Hardy, J. Roach, 1972, "A Land Use Classification System for Use with Remote Sensor Data," U.S. Geological Survey Circular 671, Washington, D.C.

Ellefsen, Richard A., 1973, "ADP Pattern Recognition of Urban Land Uses from Satellite-Borne Multispectral Scanner," Paper presented at Fourth Annual Conference on the Application of Remote Sensing of Arid Lands Studies, University of Arizona, Tucson, Arizona, November 14-16, 1973.

Ellefsen, Richard A., P. Swain, J. Wray, 1973, "Urban Land Use Mapping by Machine Processing of ERTS-1 Multispectral Data: A San Francisco Bay Area Example," Proceedings of the Conference on Machine Processing of Remotely Sensed Data, Laboratory for Applications of Remote Sensing, Purdue University, West Lafayette, Indiana, pp. 2A7-2A22.

Fitzpatrick, K.A., and H.F. Lins, Jr., 1972, "A Preliminary Evaluation of Land Use Mapping and Change Detection Capabilities Using an ERTS Image Covering a Portion of the CARETS Region," U.S. Geological Survey Technical Report GAP-ETR-3, Washington, D.C.

Lindgren, D.T., R. Simpson, W. Goldstein, 1974, "Land Use Change Detection in the Boston and New Haven Areas, 1970-1972," Final Technical Report submitted by Dartmouth College Project in Remote Sensing under Contract No. 14-08-0001-13985 to U.S. Geological Survey Geographic Applications Program.

Place, J.L., 1973, "Change in Land Use in the Phoenix (1:250,000) Quadrangle, Arizona Between 1970 and 1973: ERTS as an Aid in a Nationwide Program for Mapping General Land Use," Paper presented at the NASA/ERTS-1 Symposium, Washington, D.C., December 10-13, 1973.

Wray, James R., 1971, "A Remote Sensing System for Detecting Land Use Change in Metropolitan Areas," Paper presented at NASA/USDI/USDA Conference on Land Use Information and Classification, Washington, D.C., June 28-30, 1971.

Wray, James R., 1972, "A Preliminary Appraisal of ERTS-1 Imagery for the Comparative Study of Metropolitan Regions," Paper presented at NASA ERTS-1 Symposium, Washington, D.C., September 29, 1972.

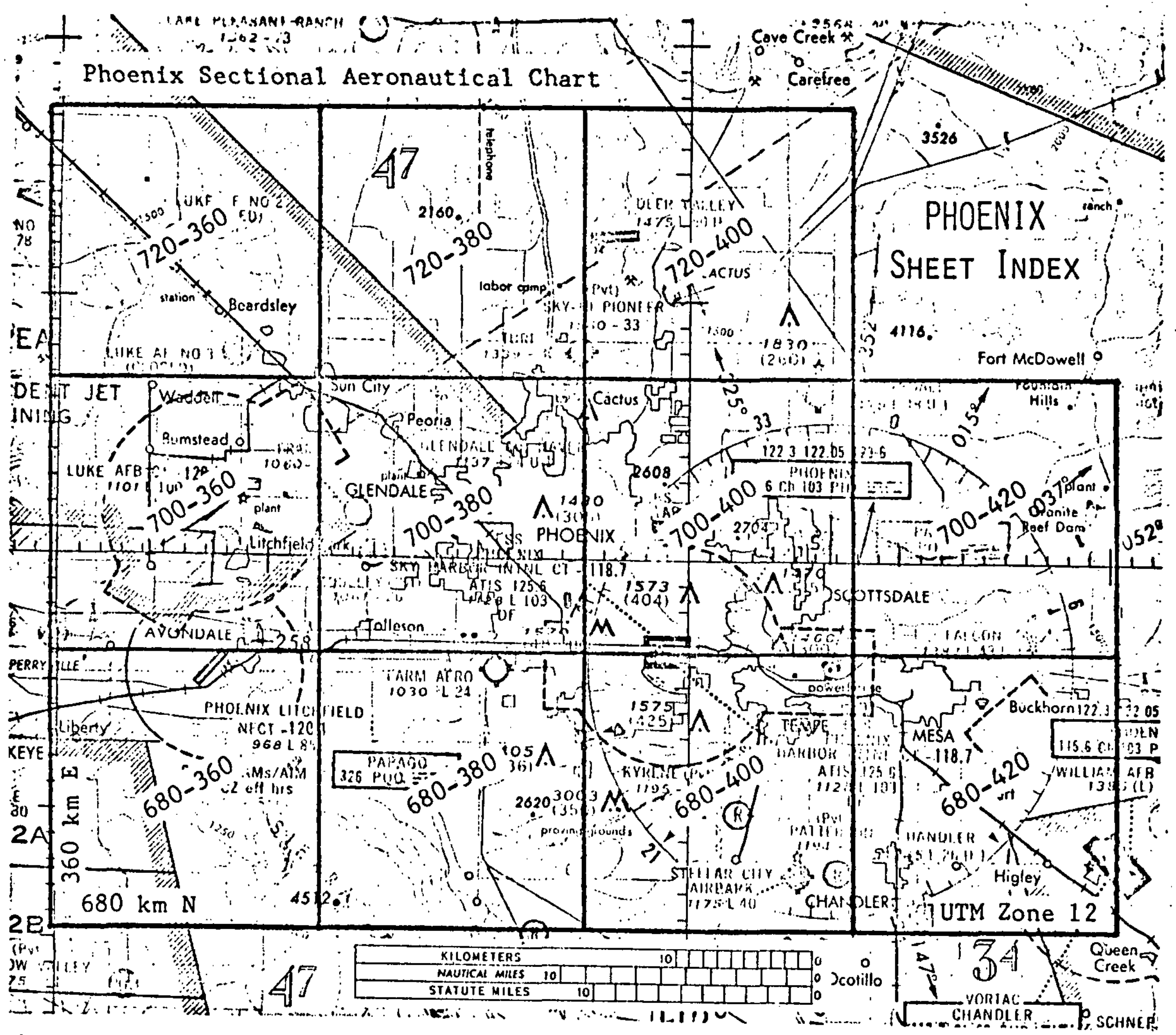


FIGURE 1. PHOENIX SHEET INDEX. Map showing eleven 20 km x 20 km sheets for which 1970 land use and 1970-1972 land use change were mapped from high-altitude aerial photography. Sheet 700-380 (shaded) is the sample area for which land use was mapped from ERTS and Skylab imagery.

LAND-USE CLASSIFICATION SYSTEM FOR USE WITH REMOTE SENSOR DATA

LEVEL I	LEVEL II
01. Urban and Built-up Land.	01. Residential.
	02. Commercial and Services.
	03. Industrial.
	04. Extractive.
	05. Transportation, Communications, and Utilities.
	06. Institutional.
	07. Strip and Clustered Settlement.
	08. Mixed.
	09. Open and Other.
02. Agricultural Land.	01. Cropland and Pasture.
	02. Orchards, Groves, Bush Fruits, Vineyards, and Horticultural Areas.
	03. Feeding Operations.
	04. Other.
03. Rangeland.	01. Grass.
	02. Savannas (Palmetto Prairies).
	03. Chaparral.
	04. Desert Shrub.
04. Forest Land.	01. Deciduous.
	02. Evergreen (Coniferous and Other).
	03. Mixed.
05. Water.	01. Streams and Waterways.
	02. Lakes.
	03. Reservoirs.
	04. Bays and Estuaries.
	05. Other.
06. Nonforested Wetland.	01. Vegetated.
	02. Bare.
07. Barren Land.	01. Salt Flats.
	02. Beaches.
	03. Sand Other Than Beaches.
	04. Bare Exposed Rock.
	05. Other.
08. Tundra.	01. Tundra.
09. Permanent Snow and Icefields.	01. Permanent Snow and Icefields.

FIGURE 2. Land Use Classification System for Use with Remote Sensor Data.

REDUCE TO 7½ INCHES

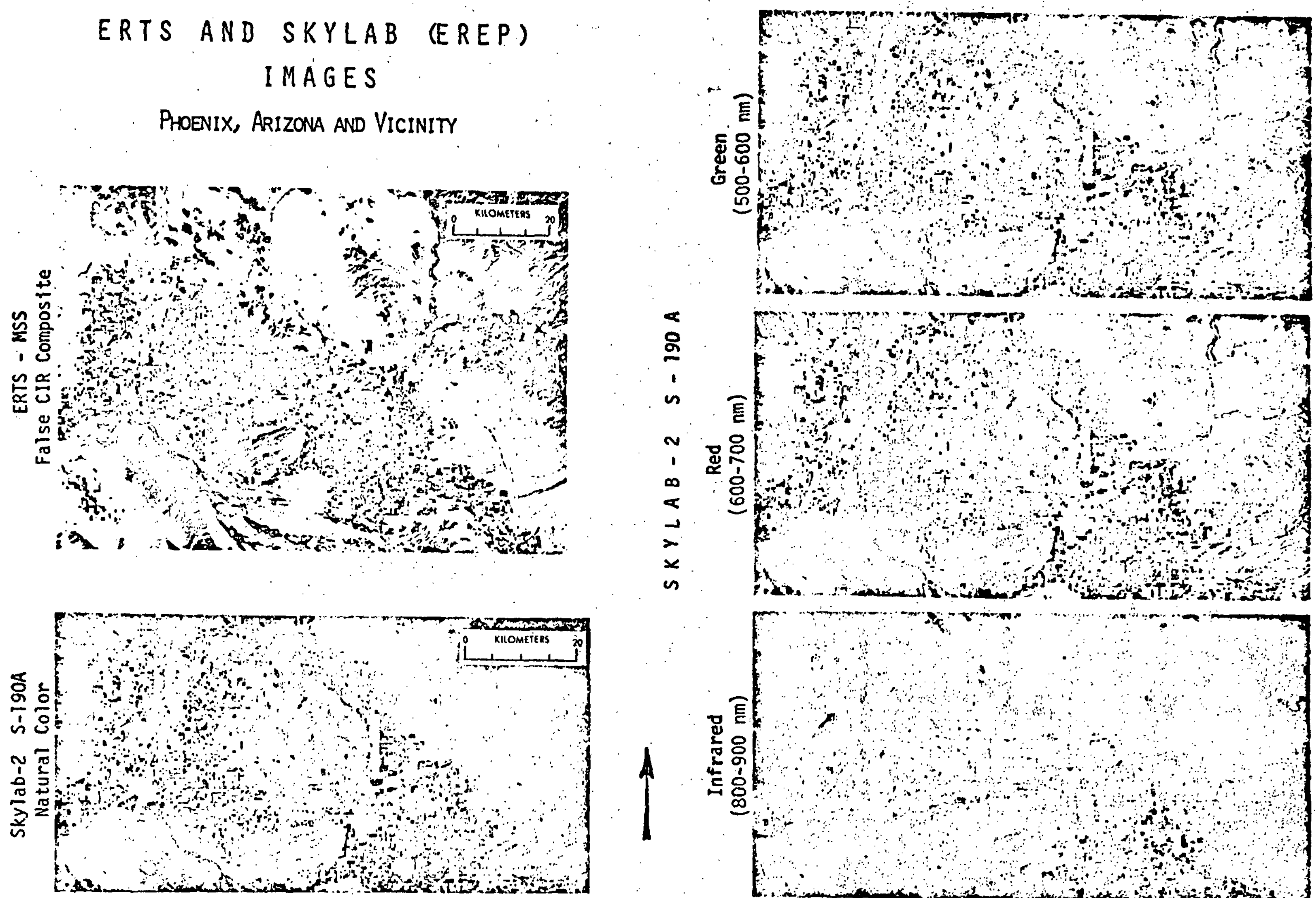


FIGURE 3. ERTS AND SKYLAB IMAGES. Portions of ERTS-1 (October 16, 1972) and Skylab-2 (June 1973) multispectral images of the Phoenix, Arizona study area. The ERTS composite was made photographically by combining MSS bands 4, 5, and 7. The Skylab photographs are those taken by the S-190A multispectral camera.

LAND USE CHANGE
1970-1973
SUN CITY, ARIZONA

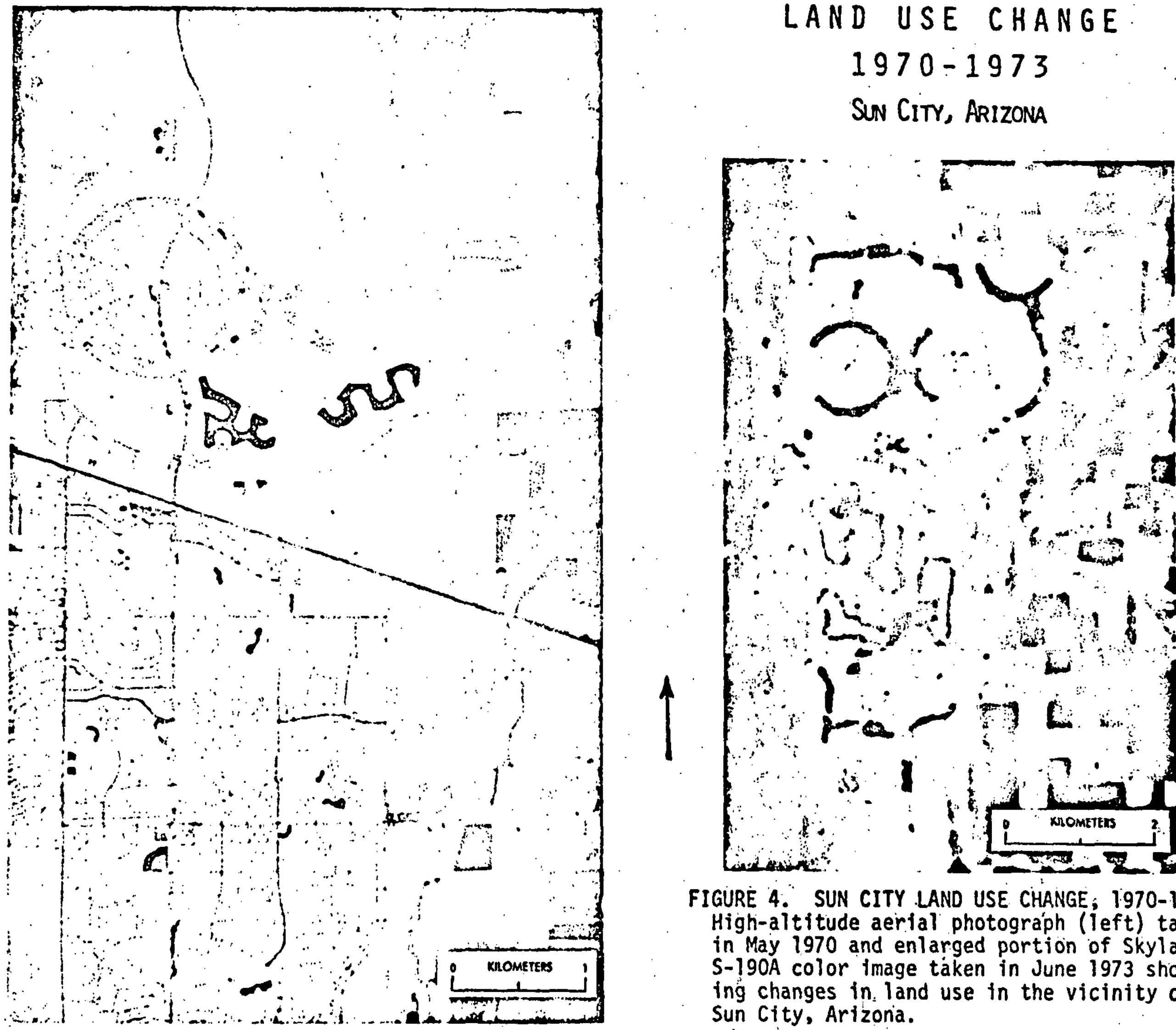


FIGURE 4. SUN CITY LAND USE CHANGE, 1970-1973. High-altitude aerial photograph (left) taken in May 1970 and enlarged portion of Skylab-2 S-190A color image taken in June 1973 showing changes in land use in the vicinity of Sun City, Arizona.

AIRCRAFT, ERTS, SKYLAB COMPARISON

PLATFORM	HIGH-ALTITUDE AIRCRAFT	ERTS-1	SKYLAB-2
SENSOR	COLOR IR PHOTOGRAPHY	MULTISPECTRAL SCANNER (False CIR Composite)	190A MULTISPECTRAL CAMERA (False CIR Composite)
GROUND RESOLUTION (meters)	4	80	40-50
ORIGINAL SCALE	1:100,000	1:3,000,000	1:2,900,000
INTERPRETATION SCALE	1:100,000	1:100,000	1:100,000
MINIMUM MAPPING UNIT (hectares)	4	4	4
LAND USE CATEGORIES MAPPED	Single-Family Residential Multi-Family Residential Commercial and Services Industrial Extractive Transportation Institutional Strip and Cluster Open and Other Cropland and Pasture Orchards, Groves Feeding Operations Desert Shrub Deciduous Evergreen Stream and Waterways Lakes Reservoirs Sand other than Beaches	Residential Mixed Commercial/ Industrial/ Institutional Extractive Transportation Open and Other Agriculture Desert Shrub Forest Streams and Waterways Lakes Reservoirs Sand other than Beaches	Residential Mixed Commercial/ Industrial/ Institutional Extractive Transportation Some Institutional Strip and Cluster Open and Other Agriculture Desert Shrub Forest Streams and Waterways Lakes Reservoirs Sand other than Beaches

TABLE 1

REDUCE TO 7½ INCHES

1970 LAND USE INTERPRETATION FROM AIRCRAFT PHOTOGRAPHY

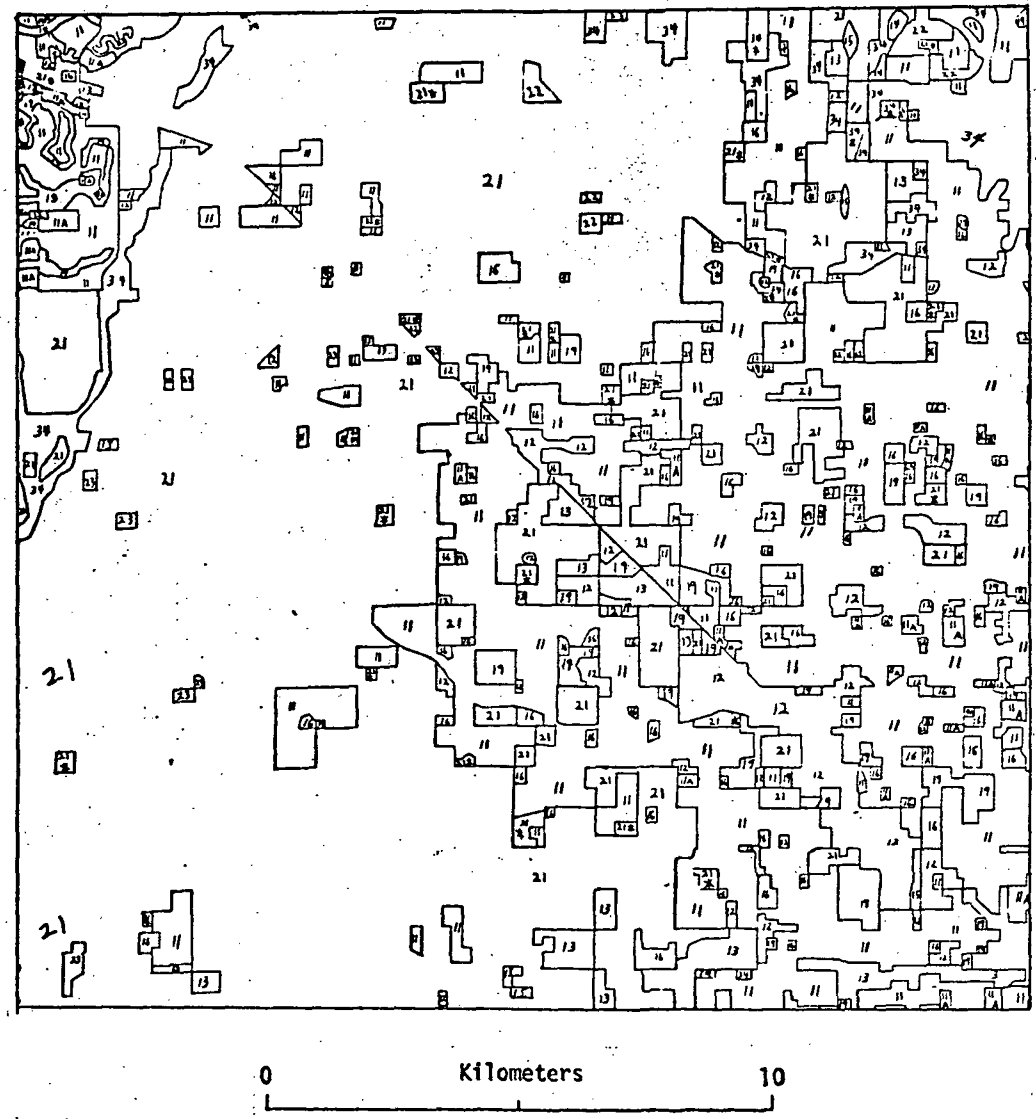
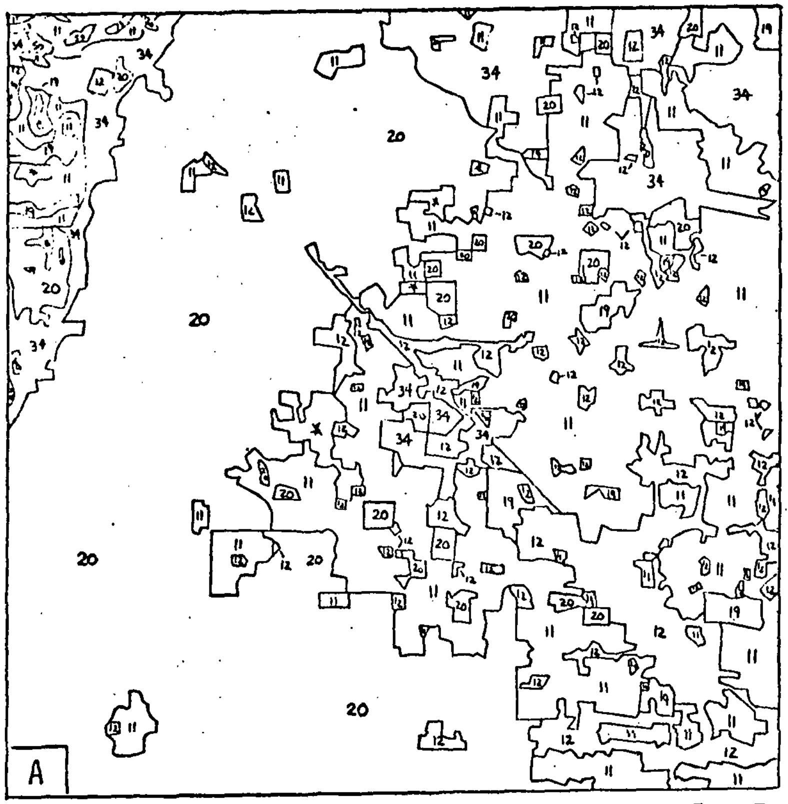


FIGURE 5. 1970 LAND USE. Land use map for a portion fo the Phoenix test site (Sheet 700-380) made from NASA high-altitude aerial photography flown in May 1970 at a scale of 1:100,000. See figure 2 for land use code identification.

LAND USE INTERPRETATION FROM ERTS-1 IMAGERY



0 Kilometers 5

LAND USE CHANGE LEGEND

	From-To
Commercial and Services	0 0
Industry	1 1
Transportation	2 2
Multi-Family Residence	3 3
Single Family Residence	4 4
Strip and Cluster Development	5 5
Agriculture	6 6
Improved Open Space	7 7
Unimproved Open Space	8 8
Water	9 9
Land Use in Trahsition	*

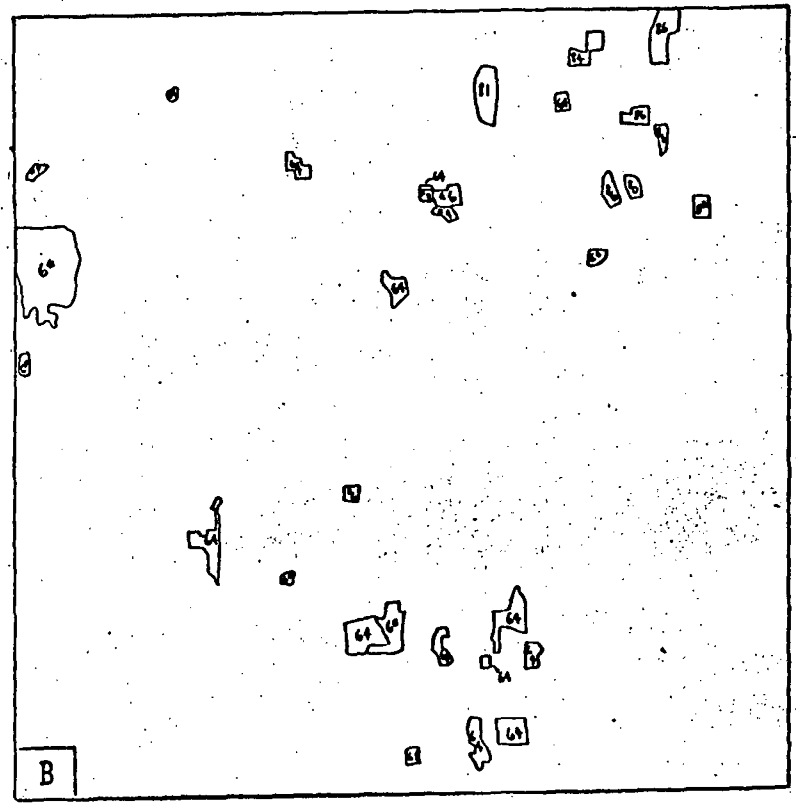


FIGURE 6A, B. LAND USE AND LAND USE CHANGE FROM ERTS. A) Land use map (see Figure 2 for land use code identification) from ERTS-1 overpass of October 16, 1972. Interpretation was made from false color IR composite enlarged to 1:100,000 scale. Asterisk (*) designates land in transition; B) Land use changes identified from comparison of October 1972 and May 1973 false color IR enlargements.

LAND USE INTERPRETATION FROM SKYLAB-2 IMAGERY

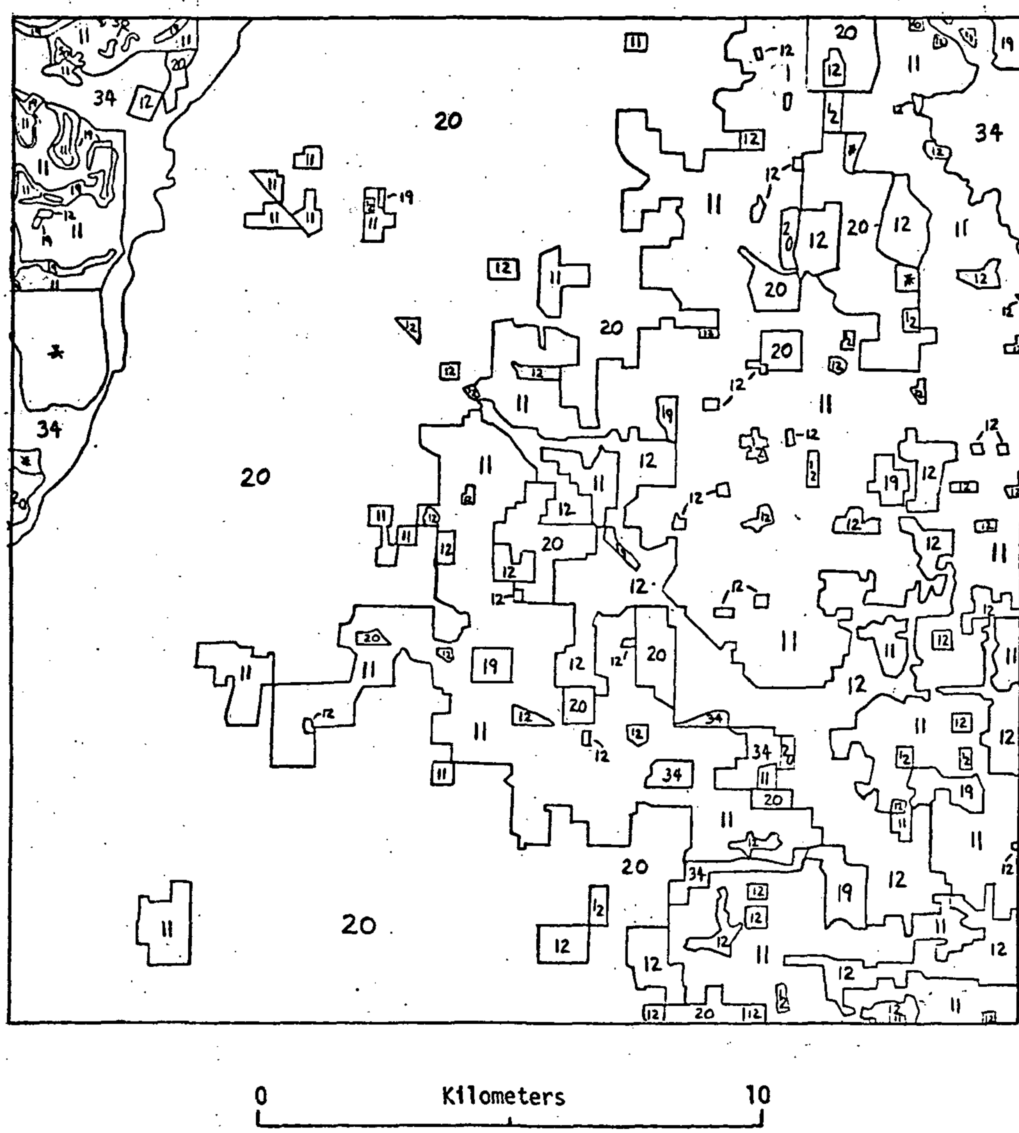
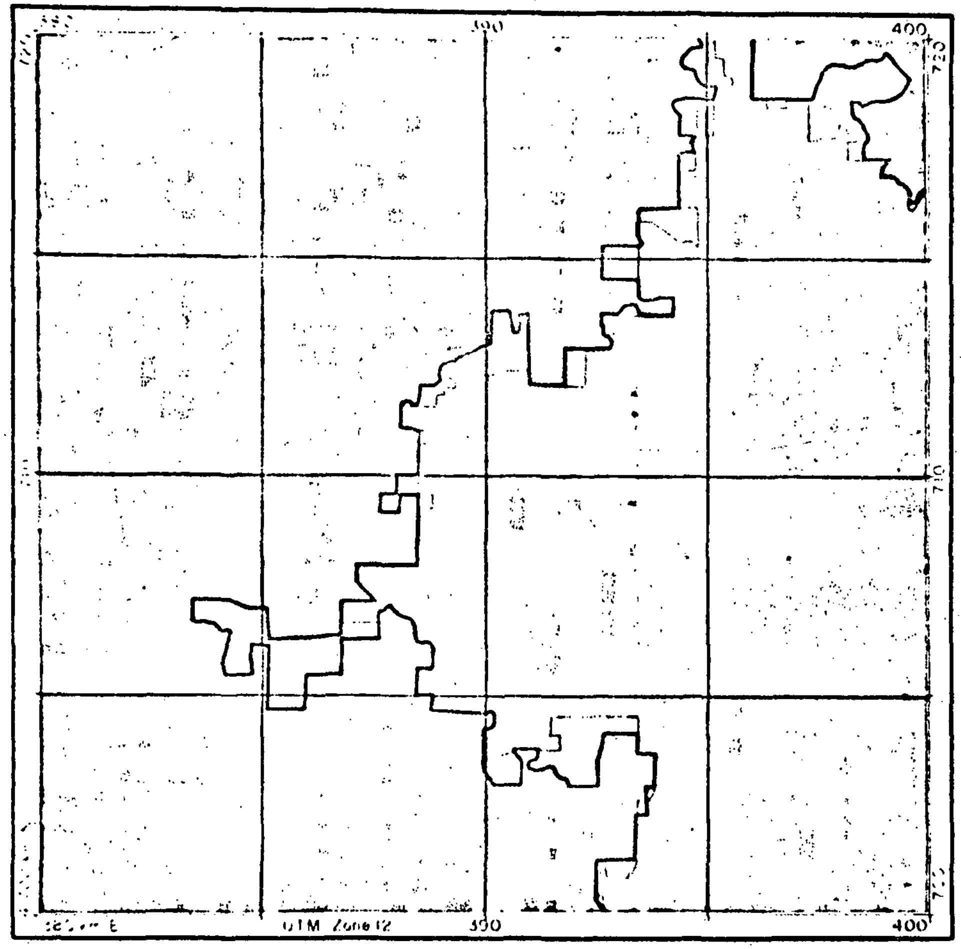


FIGURE 7. LAND USE FROM SKYLAB-2. Land use interpretation made from Skylab-2 S-190A color infrared photograph (June 1973) enlarged to 1:100,000 scale. See Figure 2 for land use code identification.

ATLAS OF URBAN AND REGIONAL CHANGE   CENSUS CITIES EXPERIMENT

Phoenix
Series 100 700-380 /20



Skylab 2 1973
High Resolution Color, S-190a

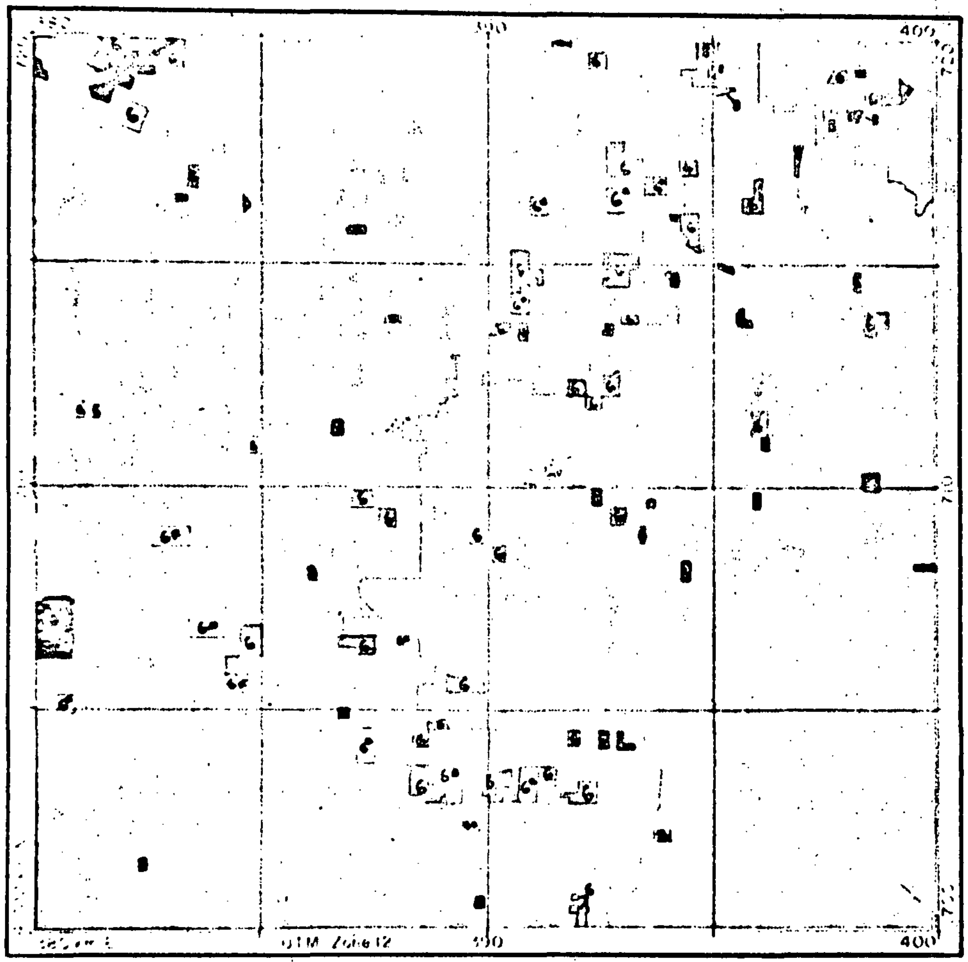
Urban Delimitation 1970
based on aircraft imagery

Urban Delimitation 1973
based on Skylab 2 imagery

FIGURE 8. 1970 AND 1973 URBANIZED AREA BOUNDARIES FOR PHOENIX SHEET 700-380. The 1970 urban area boundary (thin line) was made by drawing an unbroken continuous line around the outermost edge of the contiguous "urban and built-up" land use categories. Onto this line is superimposed a similarly defined urban and built-up boundary based on 1973 land use conditions interpreted from Skylab-2 S-190A photography.

ATLAS OF URBAN AND REGIONAL CHANGE   CENSUS CITIES EXPERIMENT

Phoenix
Series 100   **700-380 /20**



Skylab 2 .... **1973**
High Resolution Color, S-190a

Urban Delimitation .. **1970**
—— based on aircraft imagery

Land Use Change **1970-72**
.. based on aircraft imagery

From-To

Commercial and services. 0
Industry 1
Transportation 2
Multi-family residence 3
Single-family residence. 4
Strip and cluster development. . 5
Agriculture, with residence. . . 6
Improved open space. 7
Unimproved open space. 8
Water. 9

Land use in transition . . . . . •

FIGURE 9. 1970-1972 LAND USE CHANGE. 1970-1972 land use change polygons derived from aerial photo interpretation are shown superimposed onto the 1970 urbanized area boundary based on land use mapped from aerial photography.

ATLAS OF URBAN AND REGIONAL CHANGE — CENSUS CITIES EXPERIMENT

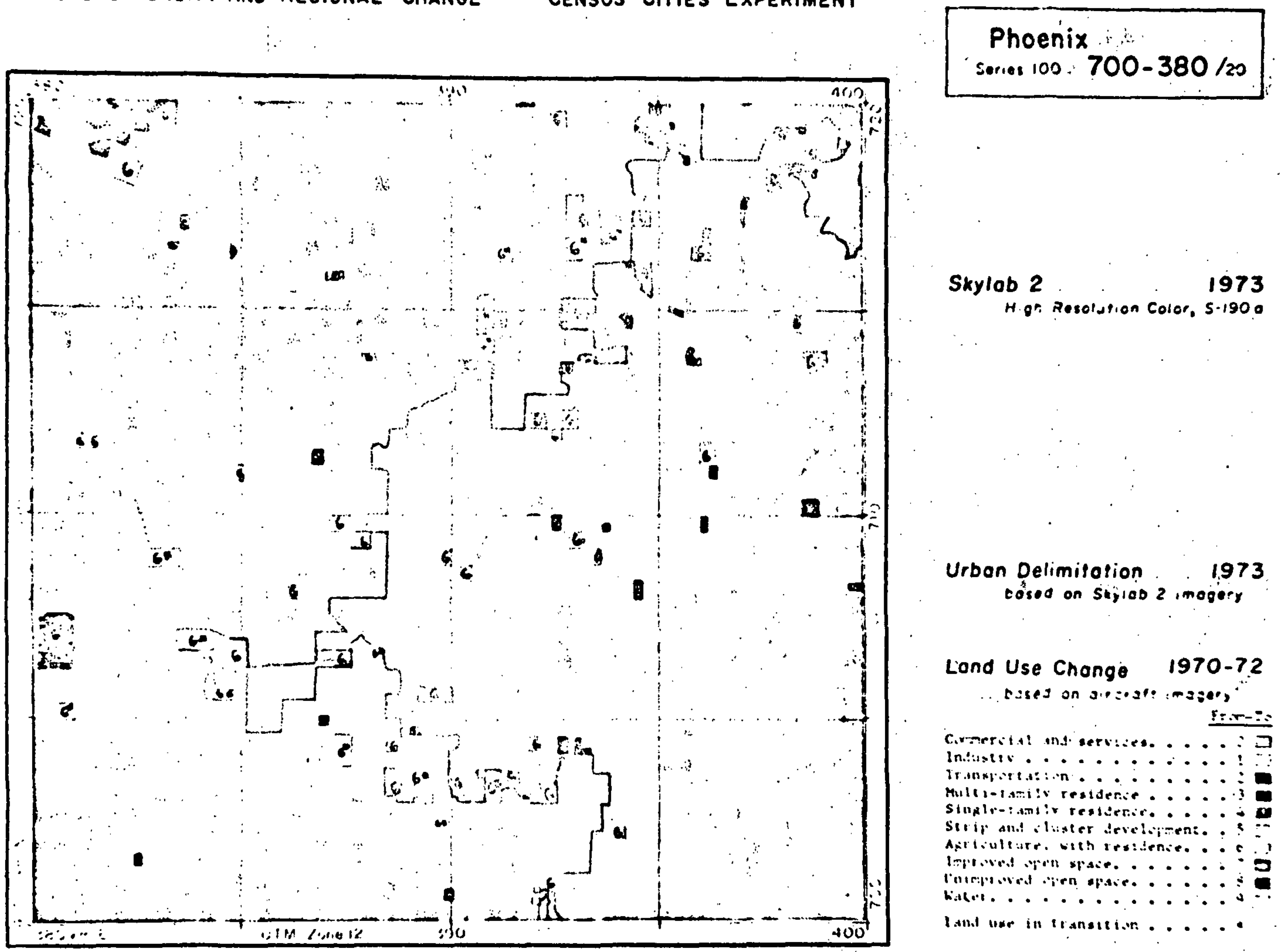


FIGURE 10. 1970-1972 LAND USE CHANGE. 1970-1972 land use change polygons derived from aerial photo interpretation are shown superimposed onto the 1973 urbanized area boundary based on land use mapped from Skylab-2 photography.